I claim:

1. Apparatus for controlling the flow of molten metal into a device for the manufacturing of articles of cast metal, the apparatus comprising:

a pressurizing conduit having an entrance, an exit, and a working area, said pressurizing conduit being resistant to the heat and corrosive effect of the molten metal being controlled,

at least one pair of electrodes at the walls of said pressurizing conduit, said electrodes being positioned to provide between them a flow of direct current substantially perpendicularly through and across said flow of molten metal,

at least one permanent neo-magnet comprising a rare-earth element,

said neo-magnet being positioned in a circuit of magnetically soft ferromagnetic material which applies north-south unidirectional magnetic flux substantially perpendicular to said working area of said pressurizing conduit, and

said magnetic flux being in a direction substantially perpendicular to both said flow of molten metal and said flow of direct current.

2. The apparatus as claimed in Claim 1, in which: said rare-earth-containing permanent neo-magnet has a midpoint differential demagnetizing permeability no greater than about 1.2 Delta gauss per Delta oersted.

3. The apparatus as claimed in Claim 1, in which: said rare-earth-containing permanent neo-magnet has a midpoint differential demagnetizing permeability no greater than about 4 Delta gauss per Delta oersted.

4. The apparatus as claimed in Claim 1, in which: said rare-earth-containing permanent neo-magnet when assembled into a suitable magnetic circuit of magnetically soft ferromagnetic material provides magnetic flux density of at least about 1.0 tesla across a non-magnetic gap as great as 38 mm.

5. The apparatus as claimed in Claim 1, in which: said rare-earth-containing permanent neo-magnet when aassembled into a suitable magnetic circuit of magnetically soft ferromagnetic material provides magnetic flux density of at least about 0.8 tesla across a non-magnetic gap as great as 38 millimeters.

6. The apparatus as claimed in Claim 1, in which: said rare-earth permanent neo-magnet comprises a material generically known as neodymium-iron-boron.

7. The apparatus as claimed in Claim 1, in which: said rare-earth permanent neo-magnet comprises a material generically known as samarium-cobalt.

8. The apparatus as claimed in Claim 1, in which: said electrodes are made primarily of carbonaceous material.

9. The apparatus as claimed in Claim 1, in which: said electrodes are made of a metal similar to the molten metal the flow of which is being controlled.

10. The apparatus as claimed in Claim 9, in which: said electrodes are cooled below their melting point by means of internal coolant passages.

11. The apparatus as claimed in Claim 1, in which:

said electrodes do not penetrate the wall of said pressurizing conduit.

12. The apparatus as claimed in claim 1, further characterized in that:

said device for manufacturing metal castings is a continuous metal-casting machine.

13. The apparatus as claimed in Claim 1, in which:

a similar apparatus of opposite magnetic polarity is placed into said magnetic circuit on the opposite side of said working area of said pressurizing conduit.

14. The apparatus as claimed in Claim 1, in which:

a plurality of rare-earth neo-magnets are divided between a first assembly placed on one side of said pressurizing conduit and a second assembly placed on the opposite side of said pressurizing conduit, and further:

said first assembly is arranged to render the pole face of its magnetically soft ferromagnetic pole piece a North magnetic pole facing said pressurizing conduit, and

said second assembly is arranged to render the pole face of its magnetically soft ferromagnetic pole piece a South magnetic pole facing said pressurizing conduit.

15. The apparatus as claimed in Claim 1, in which:

in a magnetic pole assembly, at least one magnetically soft pole piece, except for its end-face nearest said working area, is substantially surrounded by a plurality of neo-magnets which present to said pole piece faces having the same magnetic polarity throughout.

16. The apparatus as claimed in Claim 15, in which:

a plurality of magnets is made secure from their mutual repulsion in assembled position by the addition of suitably shaped pieces of non-ferromagnetic material.

17. The apparatus as claimed in Claim 15, in which:

said at least one neo-magnet on its side opposite to that side which contacts said magnetically soft ferromagnetic pole piece, is retained by a magnetically soft ferromagnetic retainer which is part of said circuit of magnetically soft ferromagnetic material.

18. The apparatus as claimed in Claim 1, further comprising:

an electronic sensor of the class comprising the sensing of the level, height, striking point, speed, or flow rate of molten metal.

19. The apparatus as claimed in Claim 18, in which:

said electronic sensor is a molten-metal-level sensor.

20. The apparatus as claimed in Claim 18, in which:

said electronic sensor is arranged to sense the striking point of an upwardly directed free jet-fountain-stream of molten metal.

21. The system comprising the apparatus as claimed in Claim 1, with the addition of:

at least two pairs of passive electrodes opposed to each other through the wall of the aforementioned pressurizing conduit, said passive electrodes being positioned across the magnetic flux of an edge area of the aforementioned unidirectional magnetic flux furnished by the aforementioned neo-magnets, said passive electrodes thereby defining a metal-flow-generated current path across the flow of molten metal, and further:

said passive electrodes are connected to an electronic controller of the aforementioned direct current applied in the aforementioned apparatus,

thereby to control the rate of flow of said molten metal.

22. The method for controlling the rate of flow of a stream of molten metal into a metal-casting device by means of electromagnetic force, said method comprising the steps of:

applying through said molten metal stream in a direction substantially perpendicular to said metal stream a unidirectional North-South magnetic field by means of at least one rare-earth-containing permanent neo-magnet in a soft-magnetic ferromagnetic circuit, while at the same time:

sending across the stream of molten metal at the same place an electrical direct current in a direction substantially perpendicular to said unidirectional North-South magnetic field, and

directing said stream of molten metal controlledly toward a metal-casting mold.

23. The method as claimed in Claim 22, in which: said mold is a continuous metal-casting machine.

24. The method as claimed in Claim 22, with the further steps of:

using an electrical signal generated by the rate of said flow to control said electrical direct current in order to adjust the speed of said flow.

25. The method as claimed in Claim 23, with the further steps of:

providing an ambient atmosphere that is inert with respect to the metal being poured to the entrance region of said continuous metal-casting machine,

projecting the flow of molten metal in a free parabolic jet-fountain-stream toward the entrance of said casting machine,

sensing the striking point of said jet-fountain-stream within the casting machine, followed by the step of:

adjusting accordingly and automatically the direct current applied to said electromagnetic pump in a closed control loop, thereby:

adjusting automatically the point of striking of said jet-fountain-stream in order to maintain a desired point of striking.

26. The method of casting a succession of identical discrete metal objects in a succession of sequentially suitably positioned identical movable molds by means of electromagnetic force upon a stream of molten metal, said method comprising the steps of:

applying through said molten metal stream in a direction substantially perpendicular to said metal stream a unidirectional North-South magnetic field by means of at least one rare-earth-containing permanent neo-magnet in a soft-magnetic ferromagnetic circuit, while at the same time:

intermittently, at the same place, starting and stopping across the stream of molten metal an electrical direct current in a direction substantially perpendicular to said unidirectional North-South magnetic field, and

directing the resulting intermittently occurring, quantitatively identical streams of molten metal sequentially into a series of substantially identical metal-casting molds held stationary for receiving their respective infillings of molten metal in order to produce a series of substantially identical metal castings.

27. Apparatus for controlling flow of molten metal comprising:

a conduit formed of non-magnetic material having a passage suitable for controlling flow of molten metal in said passage:

first and second assemblies of neo-magnets positioned on opposite sides of said conduit and being in a magnetic circuit providing an intense magnetic field B extending through said passage in a direction generally perpendicular to flow M of molten metal in said passage;

first and second electrodes mounted on opposite sides of said conduit in electrically conductive communication with molten metal within said passage; and

said first and second electrodes being suitable for connection in an electrical circuit with an electrical source of direct current for providing said first and second electrodes respectively with positive and negative voltage in said electrical circuit for causing electrical direct current I to flow through the molten metal in said passage in a direction generally perpendicular to said intense magnetic field B and also generally perpendicular to flow M of molten metal.

28. Apparatus claimed in claim 27, wherein:

said passage has a width in the direction of direct current flow I greater than its height in the direction of said intense magnetic field B.

29. Apparatus claimed in Claim 28, wherein:

said passage has a width in the direction of direct current flow I at least about five times greater than its height in the direction of said intense magnetic field B.

30. Apparatus claimed in Claim 29 wherein:
said passage has a more preferred width in the direction of direct current flow I at least about six times greater than its height in the direction of said intense magnetic field B.

31. Apparatus claimed in Claim 27, wherein:
said intense magnetic field B is at least about 5,000 gauss.

32. Apparatus claimed in Claim 31, wherein:
said intense magnetic field has a more preferred intensity of at least about 7,000 gauss throughout an area of about 26 square centimeters (about 4 square inches) of molten metal in said passage.

33. Apparatus claimed in Claim 27, wherein:
said first and second assemblies of neo-magnets include first and second pole pieces respectively positioned on opposite sides of said conduit;
said first and second pole pieces have respectively first and second pole faces in spaced parallel relationship positioned on opposite sides of said conduit and being oriented generally perpendicular to the direction of said intense magnetic field B;
said first and second pole pieces have respectively first and second pluralities of side surfaces;
said first and second assemblies of neo-magnets include first and second pluralities of neo-magnets;
said first plurality of neo-magnets include neo-magnets having North polarity pole faces adjacent to respective side surfaces of said first pole piece; and
said second plurality of neo-magnets include neo-magnets having South polarity pole faces adjacent to respective side surfaces of said second pole piece.

34. Apparatus claimed in Claim 33, wherein:

an intense magnetic field B having an intensity of at least about 14,000 gauss extends between said first and second spaced parallel pole surfaces of said first and second pole pieces.

35. Apparatus claimed in Claim 34, wherein:

said intense magnetic field B having an intensity of at least about 14,000 gauss extends throughout an area of at least about 26 square centimeters (about 4 square inches) of molten metal in said passage.

36. Apparatus claimed in Claim 31, wherein:

said intense magnetic field of at least about 5,000 gauss extends throughout an area of at least about 26 square centimeters (about 4 square inches) of molten metal in said passage.

37. Apparatus claimed in Claim 34, wherein:

said first and second spaced parallel pole faces are spaced apart about 38 millimeters (about 1.5 inches).

38. Apparatus claimed in Claim 36, wherein:

said intense magnetic field having an intensity of at least about 5,000 gauss extends through a non-magnetic gap of about 38 millimeters (about 1.5 inches); and

said conduit is positioned in said gap.

39. Apparatus claimed in Claim 35, wherein:

said intense magnetic field having an intensity of at least about 14,000 gauss extends through a non-magnetic gap of about 38 millimeters (about 1.5 inches); and

said conduit is positioned in said gap.

40. Apparatus claimed in Claim 33, wherein:

said intense magnetic field B extends in a direction generally parallel with an imaginary Z axis;

said direct current I flows through the molten metal in a direction generally parallel with an imaginary Y axis;

said flow M of molten metal is in a direction generally parallel with an imaginary X axis;

said X, Y and Z axes are mutually perpendicular;

said first and second pole pieces are configured as rectangular parallelepipeds each having two end surfaces and four side surfaces;

said first plurality of neo-magnets comprises five neo-magnets;

a first of said first plurality of five neo-magnets has its North polarity pole face adjacent to an end surface of the first pole piece and has its magnetic field generally aligned with the Z axis providing North polarity for the pole face at the other end of the first pole piece;

a second and third of said first plurality of five neo-magnets have their North polarity pole faces adjacent to respective opposite side surfaces of the first pole piece and have their respective magnetic fields generally aligned with the X axis for augmenting magnetic intensity of the North polarity pole face of the first pole piece;

a fourth and fifth of said first plurality of five neo-magnets have their North polarity pole faces adjacent to another respective opposite side surfaces of the first pole piece and have their respective magnetic fields generally aligned with the Y axis for further augmenting the magnetic intensity of the North polarity pole face of the first pol piece;

said second plurality of neo-magnets comprises five substantially cubical neo-magnets;

Claim 40 - continued

a first of said second plurality of five neo-magnets has its South polarity pole face adjacent to an end surface of the second pole piece and has its magnetic field generally aligned with the Z axis providing South polarity for the pole face at the other end of the second pole piece;

a second and third of said second plurality of five neo-magnets have their South polarity pole faces adjacent to respective opposite side surfaces of the second pole piece and have their respective magnetic fields generally aligned with the X axis for augmenting magnetic intensity of the South polarity pole face of the second pole piece; and

a fourth and fifth of said second plurality of five neo-magnets have their South polarity pole faces adjacent to another respective opposite side surfaces of the second pole piece and have their respective magnetic fields generally aligned with the Y axis for further augmenting the magnetic intensity of the South polarity pole face of the second pole piece.

41. Apparatus claimed in Claim 40, wherein:

the two end surfaces of the pole pieces are square;

said first of said first plurality of five neo-magnets is cubical and has a square North polarity pole face generally matching size of the adjacent square end surface of the first pole piece;

said square North polarity pole face of said cubical neo-magnet has its square perimeter generally aligned with the perimeter of the adjacent square end surface of the first pole piece;

Claim 41 - continued

said first of said second plurality of neo-magnets is cubical and has a square South polarity pole face generally matching size of the adjacent square end surface of the second pole piece; and

said square South polarity pole face of said cubical neo-magnet has its square perimeter generally aligned with the perimeter of the adjacent square end surface of the second pole piece.

42. Apparatus claimed in Claim 41, wherein:

all five of the neo-magnets of the first plurality of five neo-magnets are cubical and their North polarity pole faces are the same size;

an edge of the North polarity pole face of the second, third, fourth and fifth neo-magnets is aligned with an edge of the square end surface of the first pole piece adjacent to the North polarity pole face of the first neo-magnet of the first plurality of five neo-magnets;

all five of the neo-magnets of the second plurality of five neo-magnets are cubical and their South polarity pole faces are the same size; and

an edge of the South polarity pole face of the second, third, fourth and fifth neo-magnets is aligned with an edge of the square end surface of the second pole piece adjacent to the South polarity pole face of the first neo-magnet of the second plurality of neo-magnets.

43. Apparatus claimed in Claim 40, wherein:

non-magnetic material is adjacent to all five of the neo-magnets of the first plurality of neo-magnets for keeping them in their respective positions; and

non-magnetic material is adjacent to all five of th neo-magnets of the second plurality of neo-magnets for keeping them in their respective positions.

44. Apparatus claimed in Claim 40, wherein:

a first pancake cooling layer is interposed between said North polarity pole face of the first pole piece and said conduit;

a second pancake cooling layer is interposed between said South polarity pole face of the second pole piece and said conduit; and

each of said pancake cooling layers contains cooling passages therein.

45. Apparatus claimed in Claim 42, wherein:

eight cubical non-magnetic filler blocks of the same size as said cubical neo-magnets are positioned around said first cubical neo-magnet of said first plurality of five cubical neo-magnets;

said eight cubical non-magnetic filler blocks are arrayed with said first cubical neo-magnet in a square layer configuration aligned with a plane parallel with the X and Y axes;

four cubical non-magnetic filler blocks of the same size as said cubical neo-magnets are positioned adjacent to side corners of the first pole piece;

said four cubical non-magnetic filler blocks are arrayed with said second, third, fourth and fifth cubical neo-magnets of said first plurality of five cubical neo-magnets and with the first pole piece in a square layer configuration aligned with a plane parallel with the X and Y axes;

eight cubical non-magnetic filler blocks of the same size as said cubical neo-magnets are positioned around said first cubical neo-magnet of said second plurality of five cubical neo-magnets;

Claim 45 - continued

said eight cubical non-magnetic filler blocks are arrayed with said first cubical neo-magnet of said second plurality of five neo-magnets in a square layer configuration aligned with a plane parallel with the X and Y axes;

four cubical non-magnetic filler blocks of the same size as said cubical neo-magnets are positioned adjacent to corners of the second pole piece; and

said four cubical non-magnetic filler blocks are arrayed with said second, third, fourth and fifth cubical neo-magnets of said second plurality of five cubical neo-magnets and with the second pole piece in a square layer configuration aligned with a plane parallel with the X and Y axes.

46. Apparatus claimed in Claim 27, wherein:

a first pancake cooling layer is interposed between said first assembly of neo-magnets and said conduit;

a second pancake cooling layer is interposed between said second assembly of neo-magnets and said conduit; and

each of said pancake cooling layers has cooling passages therein.